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MAY 1 1906

OSMOTIC PRESSURE IN PLANT CELLS

—:—

A

THESIS

submitted in partial satisfaction of the
requirement for the

DEGREE OF M. S.

in the

UNIVERSITY OF CALIFORNIA

John Edward Clark

BERKELEY

1906

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I undertook and carried out this series of experiments at the suggestion of and under the disection of Dr. W. J. V. Osterhout, and the results obtained strongly sustain if not positively confirm his theory that osmotic pressure is not alone responsible for the conveyance of solutions through the membranes and walls of plant cells.

As is now generally conceded the living plant cell is an osmotic system in which the protoplasm serves as a semi-permeable membrane, i. e. a membrane which will allow water to pass to or from the cell but not the dissolved salt which may be contained in solution. When the cell dies

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the protoplasm loses its semi-permeable property, at least partially, and some of the cell content passes into the outer solution. Not unlikely the inner and outer solutions intermix until equilibrium is established.

The cell is surrounded by two walls, the outer thick cellulose wall which is permeable to both water and solutes, and the inner protoplasmic membrane. It is this thin protoplasmic membrane which is semi-permeable. When the cell loses water the protoplasm contracts and the protoplasmic membrane is pulled away from the outer cellulose wall, a condition termed (plasmalysis). This may be brought about by placing the cell in a solution of greater concentration than that of the cell sap.

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For vegetable material the ordinary red table beet was chosen because the red coloring matter of the cells furnishes an accurate means of determining the relative longevity and condition of the cells in the different solutions, and permits of checking the results obtained in large blocks by parallel plasmalytic observations.

The beets were taken from one garden only, in order to obtain material of as uniform composition as possible.

After determining the freezing point depression and concentration of the cell sap the several solutions were made up as shown in the tables.

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The greatest possible care was excercised in selecting the salts used. The best C. P. material of different firms was obtained and special tests made for comparative purity. Likewise the water used was distilled from $KMnO_4$ in large flasks specially prepared for physiological purposes. These precautions are particularly essential in plasmolytic determinations.

The blocks of beet tissue were cut of uniform size in a miter box, then placed in graduated cylinders containing the solutions, and the cylinders next put into a water bath at a constant temp. of 25° C.

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At definite regular intervals as given in the tabulated data the blocks were removed, dried, weighed and the volumes taken giving the results as shown.

Curve (2) plate 2 is taken from data obtained in a preliminary series and is plotted to show that irregularity in lower portion of curve (1) is apparently an error and should be as dotted line. These cane sugar curves correspond most closely to the theoretical osmotic pressure curves, i. e. of the curves having molecular strength for abcissa and percentage gain $\pm$ for ordinates. But by changing the the abcissa to F. P. depressions as in plate 4, they approach more closely the theoretical

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curve. The above curves, to comply with the requirements of the osmotic pressure theory, should be straight lines. What the exact factor is which enters in to cause the curve has not been satisfactorily explained.

It would appear from the tabulated data that the cells gain in weight in solutions above isotonic concentrations, i. e. that isotonic solutions are not isosmotic. But when we compare the curves in plate 4 and note that the cells gained unequally in the distilled water control, and that if these points were made to coincide, the curves would much more nearly coincide. Possibly the variance then would fall within the experimental error.

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The curves having time for abcissa and percentage given for ordinates, should theoretically be straight lines, which is only true in fact, in case of the isotonic or nearly isotonic solutions. Nor can it be attributed to the death of the cell, for taking the cane sugar curves, plate (3). while the gain in distilled water, which becomes minus in 42 hours, may be said to be due to the death of the cells, yet several of the curves from the more concentrated solutions indicate that, while the gain is rapidly negative up to about 18 hours, after which time it is quite as rapidly positive, showing that the cells are not dead and that there is some factor other than osmotic pressure existing.

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<C12H22O11> Wt of Beets × Vol of Beets. cc >

Solutions	Original Wt	After Six Hours	After Eighteen Hours.	After Forty-two Hours.	Original Vol	Vol. after Six Hours	Vol. after Eighteen Hours	Vol. after Forty-Two Hours.
		-35.8 %	- 44.1%	- 43.0%				
1.4 M	13.755	8.830	7.680	7.750	1340	790	6.70	6.75-
		- 26.4%	- 30.7%	- 29.4%				
1.2 M	12.945	9.532	8980	9.145-	12.62	8.70	8.25-	8.30
		- 28.7%	- 32.3%	- 26.3%				
1.0 M	13.095	9.335-	8.860	9.645-	12.77	8.65-	8.10	8.60
		- 20.2%	- 21.3%	- 17.4%				
0.8 M	12.645	10.090	9.95-5-	10.440	12.34	9.75-	9.40	10.05-
		- 8.4%	- 10.3%	- 10.2%				
0.6 M	12.895	11.810	11.560	11.585-	12.58	11.40	11.15-	11.20
		- 1.8 %	- 1.4 %	- 2.0 %				
0.4 M	13.465-	13.215-	13.263	13.195-	13.13	13.05-	13.00	12.70
		+ 2.3 %	+ 2.8%	+ 2.7 %				
0.2 M	12.680	12.970	13.040	13.030	12.37	12.55-	12.70	12.55-
		+ 6.6 %	+ 8.3 %	- 0.7 %				
Dist. H2O	13.575	14.470	14.705-	13.470	13.24	14.00	14.30	13.25-
		+ 0.4 %	+ 0.4 %	+ 0.8				
.32 M Isotonic	12.650	12.650	12.650	12.700	12.19	12.20	12.05-	12.15-

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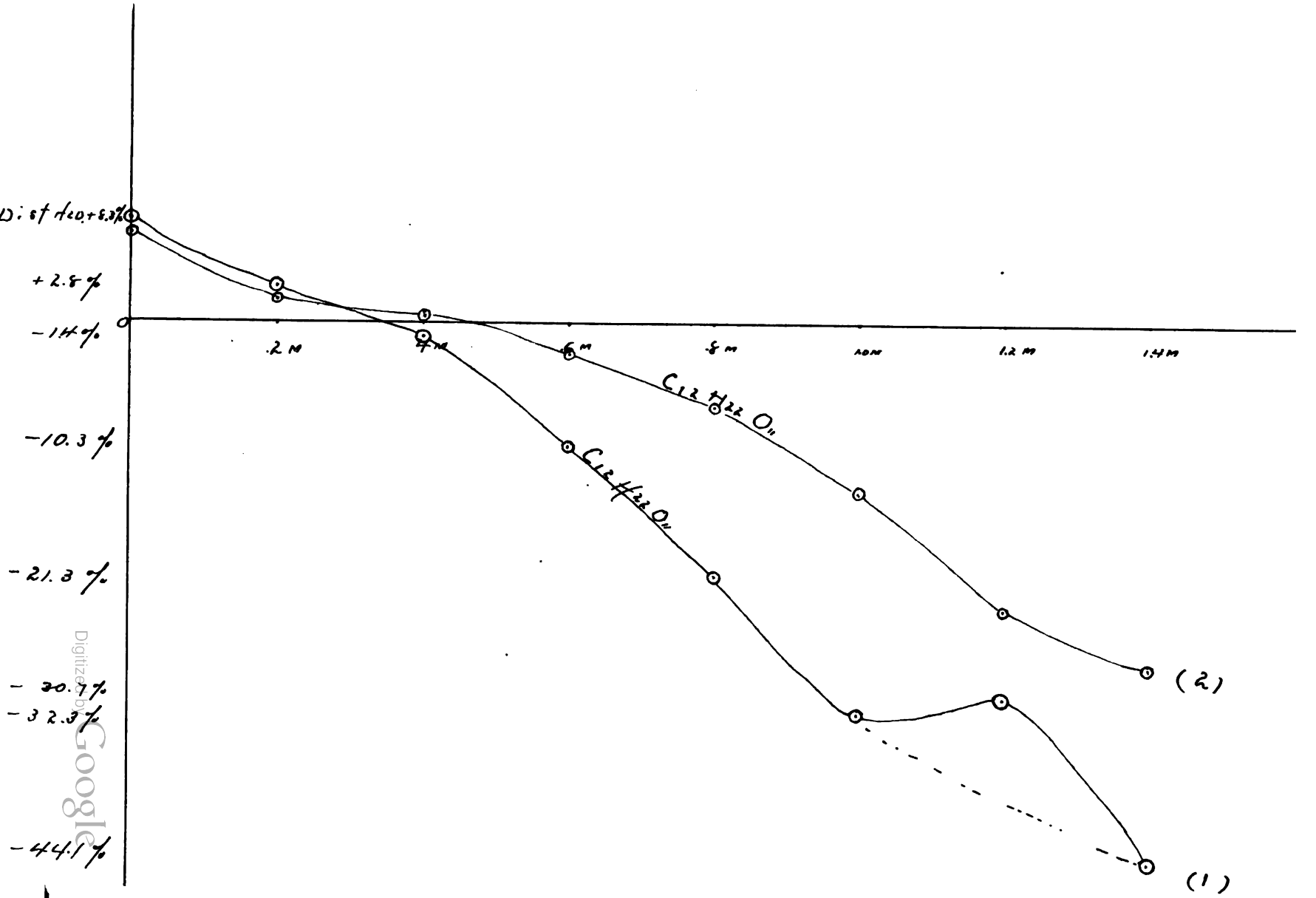
3 div. = .1 M
1 " = 2% gain ±

Curves based upon eighteen hour observations.



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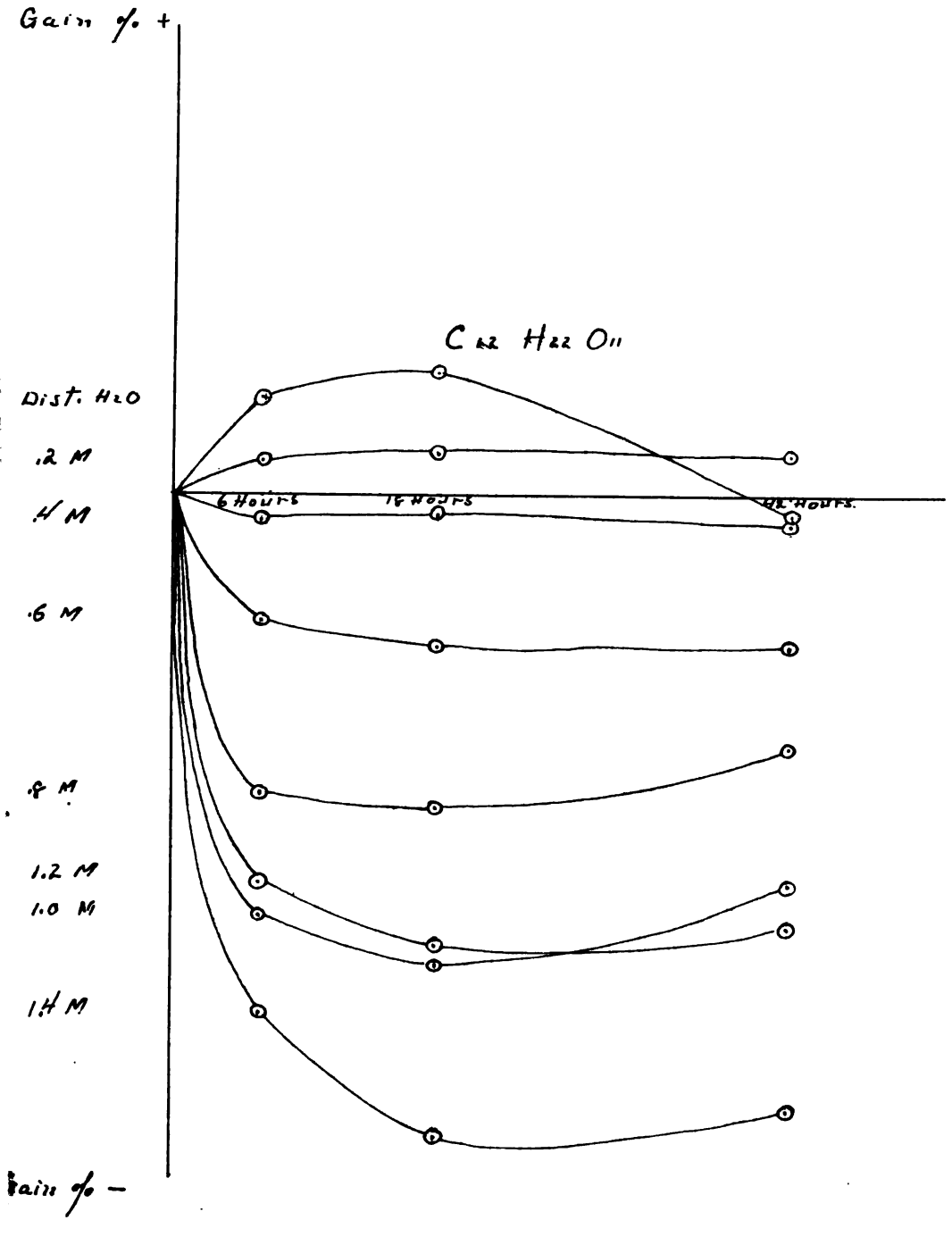
1 div. = 2% gain +
1 " = 2 Hours.



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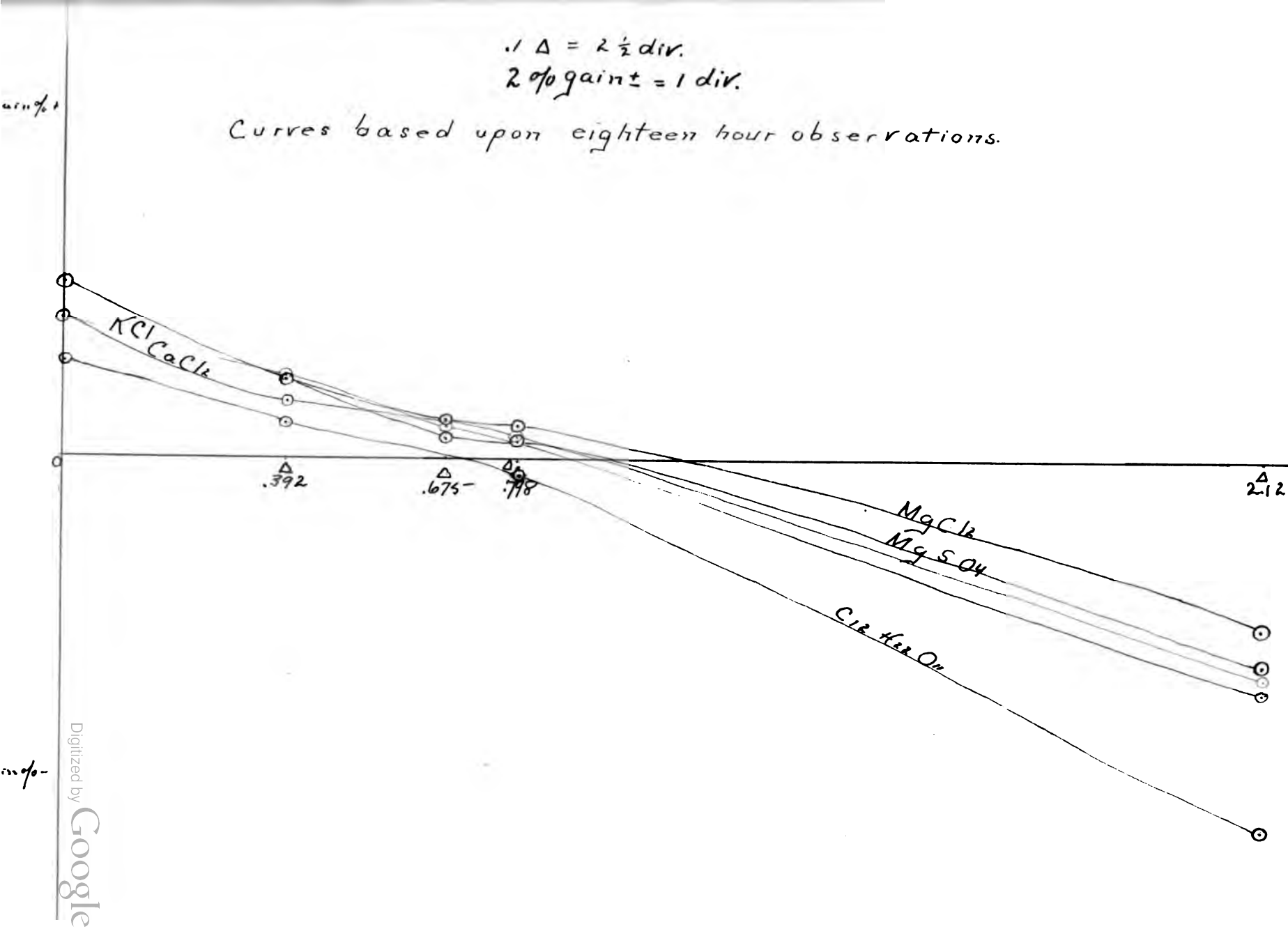
.1 Δ = 2½ div.

2% gain ± = 1 div.

Curves based upon eighteen hour observations.



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<MgSO4		Wt. of Beets				Vol. of Beets.		
Solutions	Original Wt	After six Hours	After Eighteen Hours	After Forty-two Hours	Original Vol. CC	Vol. after six Hours	Vol. after Eighteen Hours	Vol. after Forty-two Hours
		− 15.2%	− 17.8%	−17.4%				
.977 M	10.495	8.900	8.630	8.680	960cc	8.41	790	800
		+ 1.50%	+ 1.4%	+ 1.2%				
.375 M	9.355	9.490	9.480	9.470	9.15	9.11	9.10	90.50
		+ 1.4%	+ 1.5%	+ 1.1%				
Isotonic .321 M	10.295	10.440	10.455	10.415	10.00	10.10	10.15	10.10
		+ 6.3%	+ 6.7%	+ 5.5%				
.174 M	10.450	11.110	11.155	11.030	10.25	10.82	10.85	10.80
<MgCl2		− 16.5%	− 14.6%	−13.9%				
.480 M	10.090	8.445	8.635	8.700	9.85	8.00	8.15	8.20
		+ .3.1%	+ 2.8%	+ 2.5%				
.160 M	10.340	10660	10.645	10.605	10.10	10.50	10.45	1040
		+ 3.4%	+ 3.4%	+ 3.6%				
Isotonic .130 M	10.400	10775	10.775	10.790	10.20	10.55	10.80	1050
		+ 6.0%	+ 6.6%	+ 6.0%				
.070 M	10.660	11.305	11.365	11.300	10.30	10.95	11.10	11.05
		+ 12.0%	+ 15.3%	+ 13.1%				
Dist. H2O	9.635	10.790	11.115	10.900	10.40	10.40	10.90	10.65

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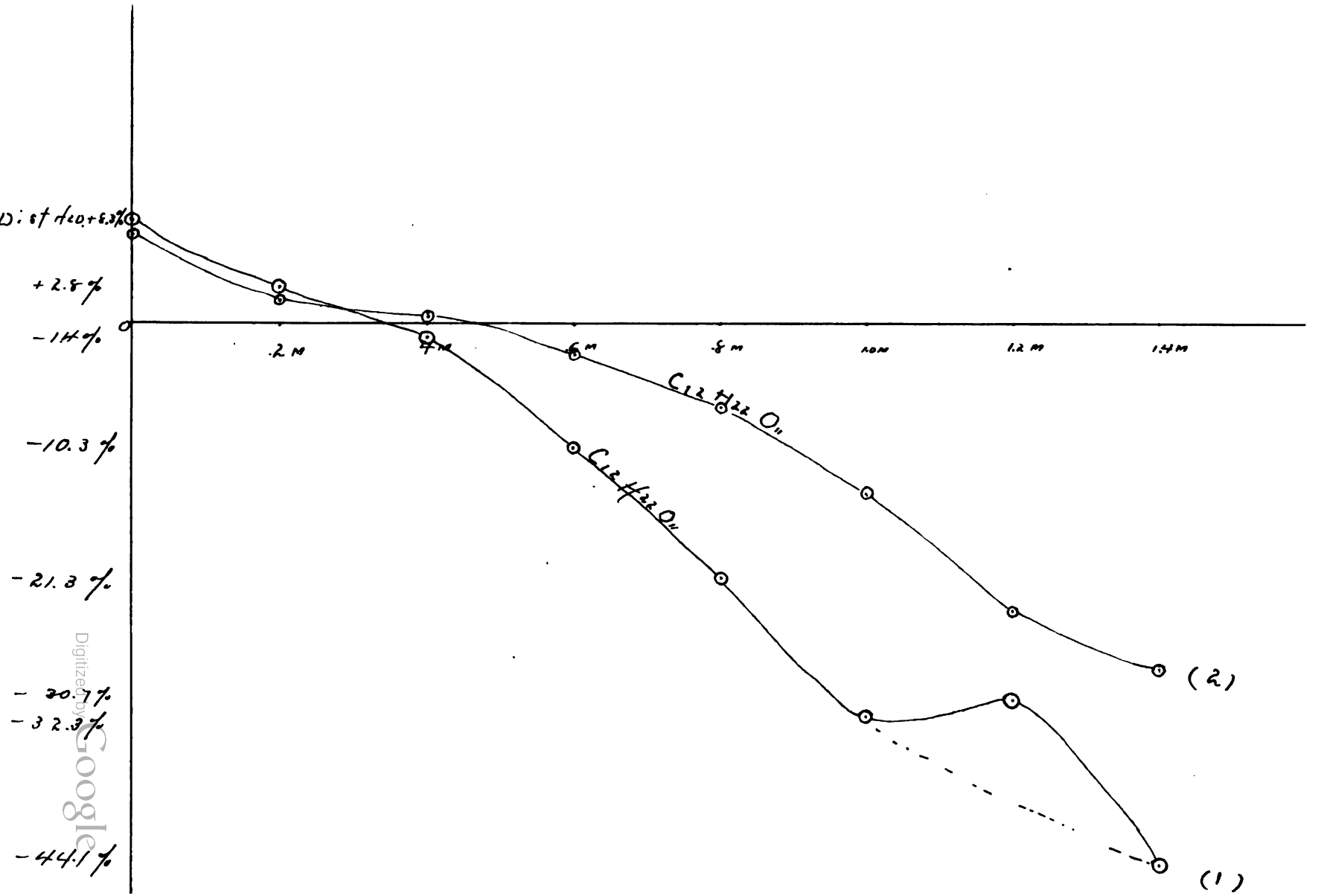
3 div. = .1 M
1 " = 2% gain ±

Curves based upon eighteen hour observations.



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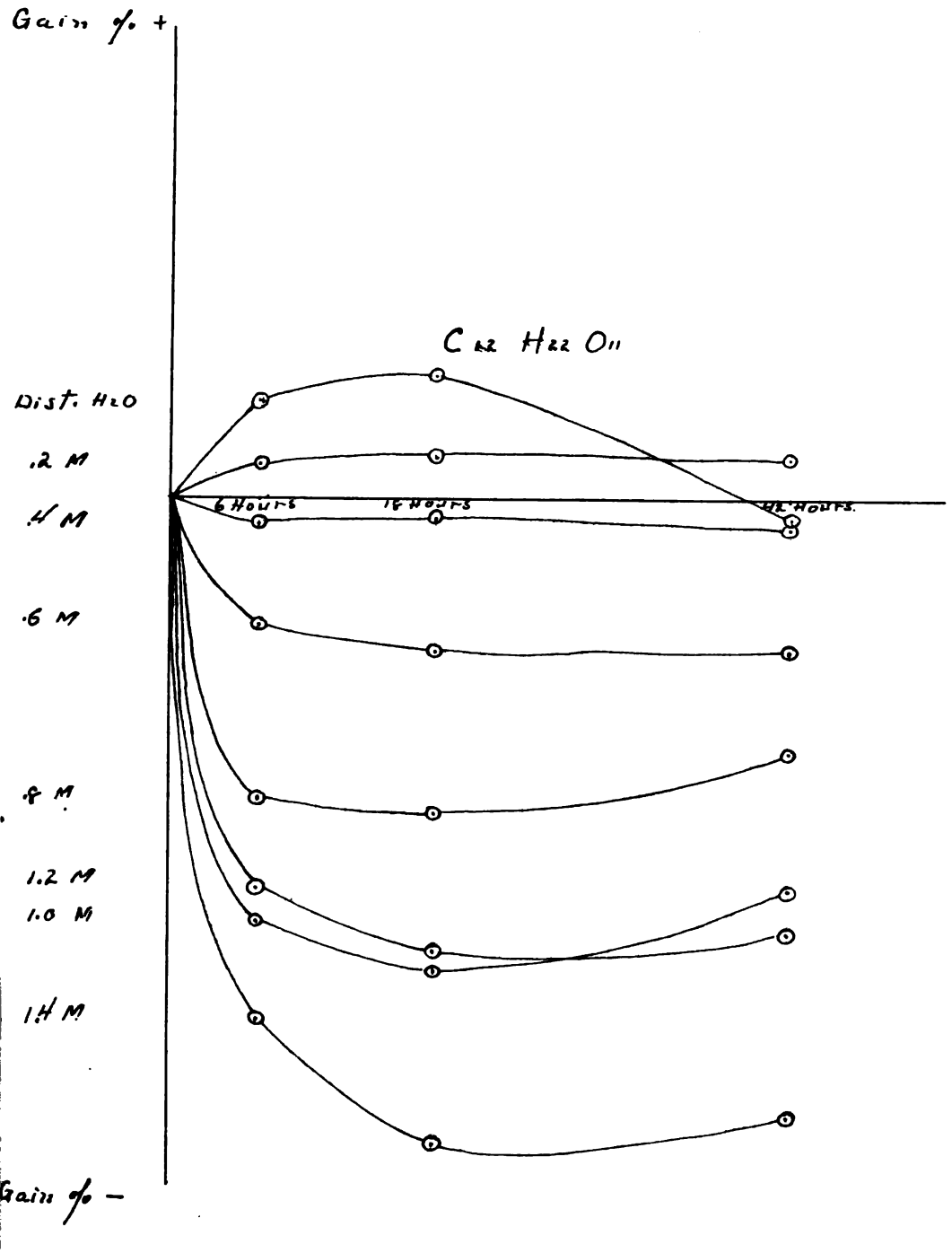
1 div. = 2% gain ±
1 " = 2 hours.



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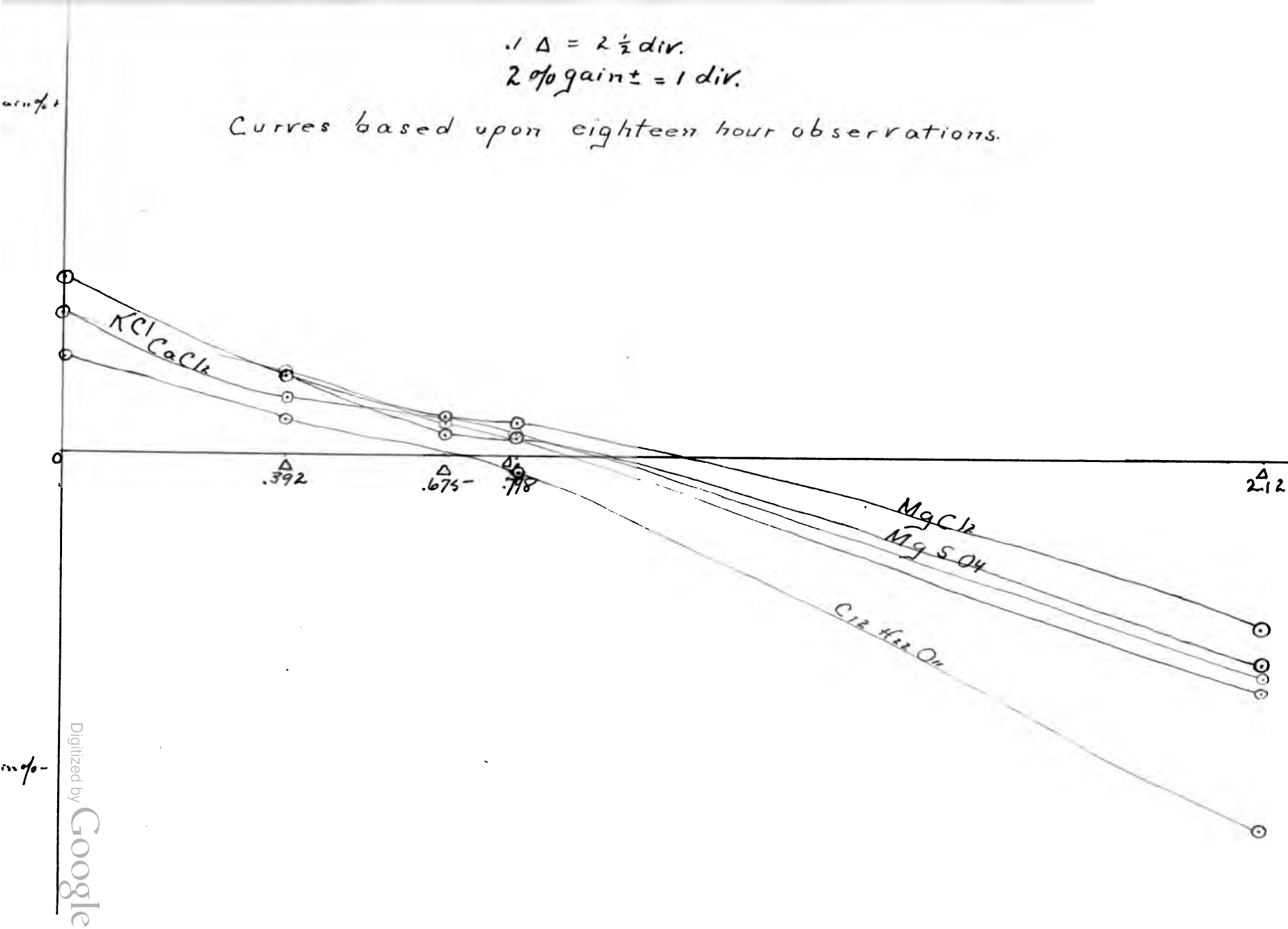
.1 Δ = 2½ div.

2 % gain ± = 1 div.

Curves based upon eighteen hour observations.



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MgSO4	Wt. of Beets			Vol. of Beets.			
Solutions	Original wt.	After six Hours	After Eighteen Hours	After Forty-two Hours	Original Vol. cc	Vol. after Six Hours	Vol. after Eighteen Hours	Vol. after Forty-two Hours
		− 15.2%	− 17.8%	−17.4%				
.977 M	10.495	8.900	8.630	8.680	9.60cc	8.41	790	800
		+ 11.50%	+ 1.4%	+ 1.2%				
.375 M	9.355	9.490	9.480	9.470	9.15	9.11	9.10	90.50
Isotonic		+ 1.4%	+ 1.5%	+ 1.1%				
.321 M	10.295	10.440	10.455	10.415	10.00	10.10	10.15	10.10
		+ 6.3%	+ 6.7%	+ 5.5%				
.174 M	10.450	11.110	11.155	11.030	10.25	10.82	10.85	10 80
MgCl2		− 16.5%	− 14.6%	−13.9%				
.480 M	10.090	8.445	8.635	8.700	9.85	8.00	8.15	8.20
		+ .3.1%	+ 2.8%	+ 2.5%				
.160 M	10.340	10660	10.645	10.605	10.10	10.50	10.45	1040
		+ 3.4%	+ 3.4%	+ 3.6%				
Isotonic .130 M	10.400	10775	10.775	10.790	10.20	10.55	10.50	1050
		+ 6.0%	+ 6.6%	+ 6.0%				
.070 M	10.660	11.305	11.365	11.300	10.30	10.95	11.10	11.05
		+ 12.0%	+ 15.3%	+ 13.1%				
Dist. H2O	9.635	10.790	11.115	10.900	10.40	10.40	10.90	10.65

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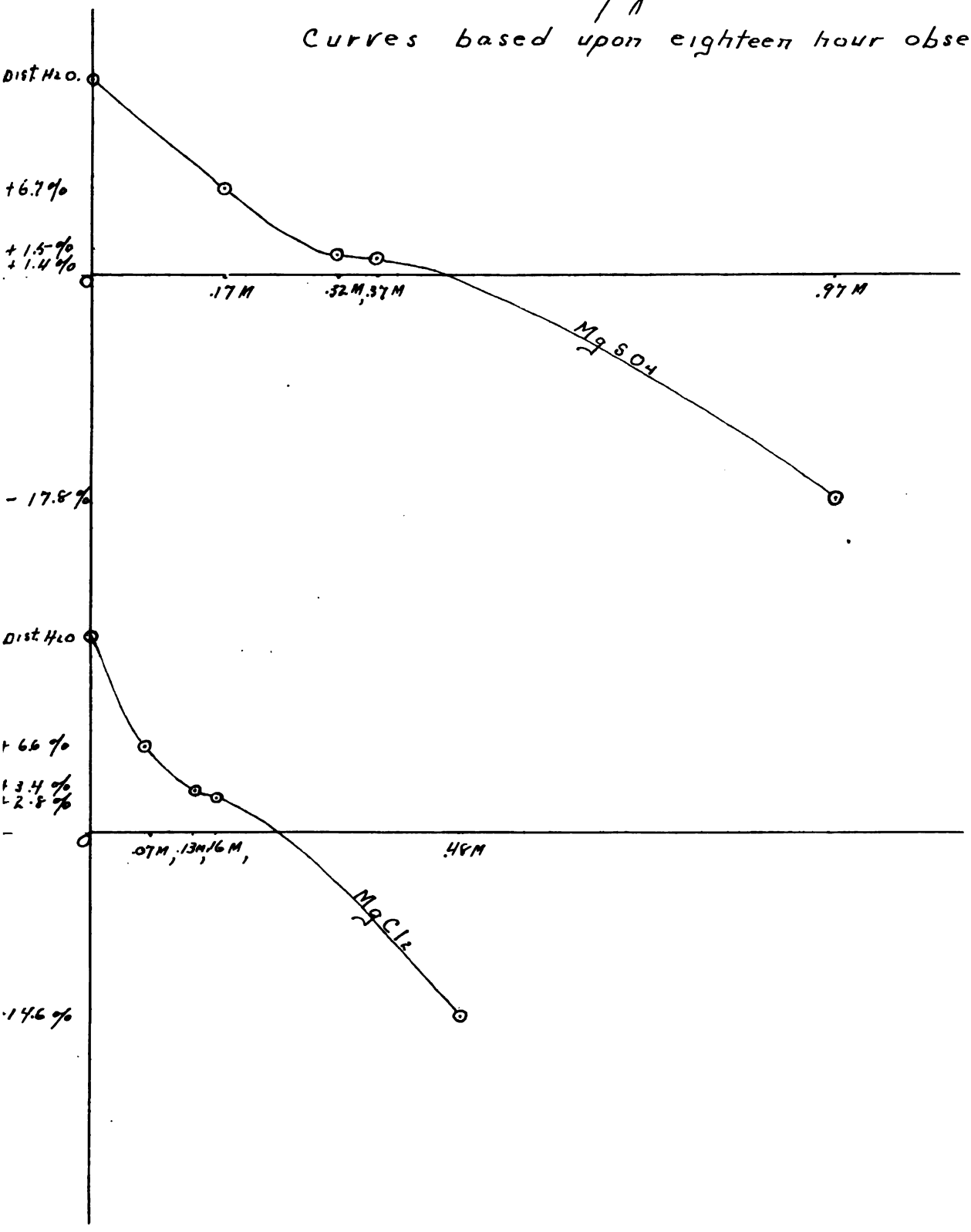
8 div. = .1 M
1 " = 2% gain ±

Curves based upon eighteen hour observation.



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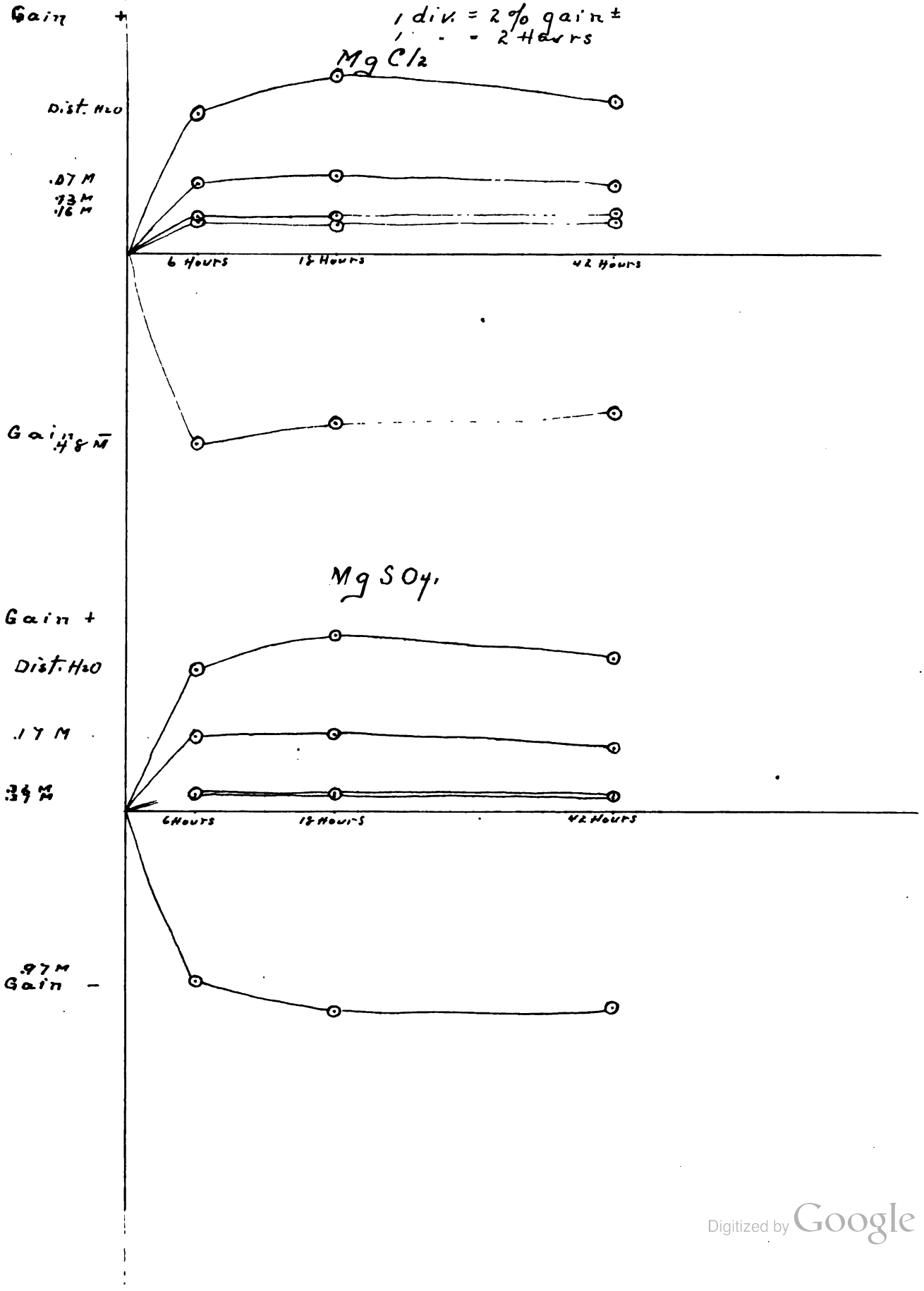

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"CaCl2"		Wt. of Beets.			Vol. of Beets.			
Solutions	Original wt.	After Six Hours.	After Eighteen Hours.	After Forty Two Hours.	Original Vol.	Vol. After Six Hours.	Vol. After Eighteen Hours.	Vol. After Forty Two Hours.
.41 M	9.685-	- 20.4% 7.705-	- 19.2% 7.825-	- 19.1% 7.835-	9.3	7.25-	7.3	7.35-
.16 M	9.910	+ 1.5- % 10.065-	+ 1.8 % 10.095-	+ 1.7 % 10.080	9.5-	9.9	9.8	9.8
Isotonic .13 M	11.260	+ 3.1 % 11.615-	+ 3.5- % 11.665-	+ 3.7 % 11.680	11.2	11.3	11.4	11.45-
.08 M	10.750	+ 4.5- % 11.235-	+ 4.9 % 11.285-	+ 5.1 % 11.310	10.3	10.9	11.0	11.1
KCl .64 M	10.795-	- 21.5- % 8.465-	- 20.1 % 8.625-	- 17.8 % 8.870	10.3	8.0	8.1	8.8
.23 M	9.880	+ 1.1 % 9.995-	+ 1.4 % 10.020	+ 2.0 % 10.085-	9.4	9.7	9.8	9.8
Isotonic .19 M	9.340	+ 2.8 % 9.605-	+ 3.0 % 9.635-	+ 3.6 % 9.680	9.0	9.2	9.3	9.35-
.11 M	10.370	+ 5.4 % 10.935-	+ 7.0 % 11.105-	+ 0.8 % 10.460	10.0	10.6	10.8	10.1
Dist. H2O	11.050	+ 8.5- % 11.995-	+ 12.0 % 12.385-	+ 13.4 % 12.540	10.7	11.8	12.1	12.2

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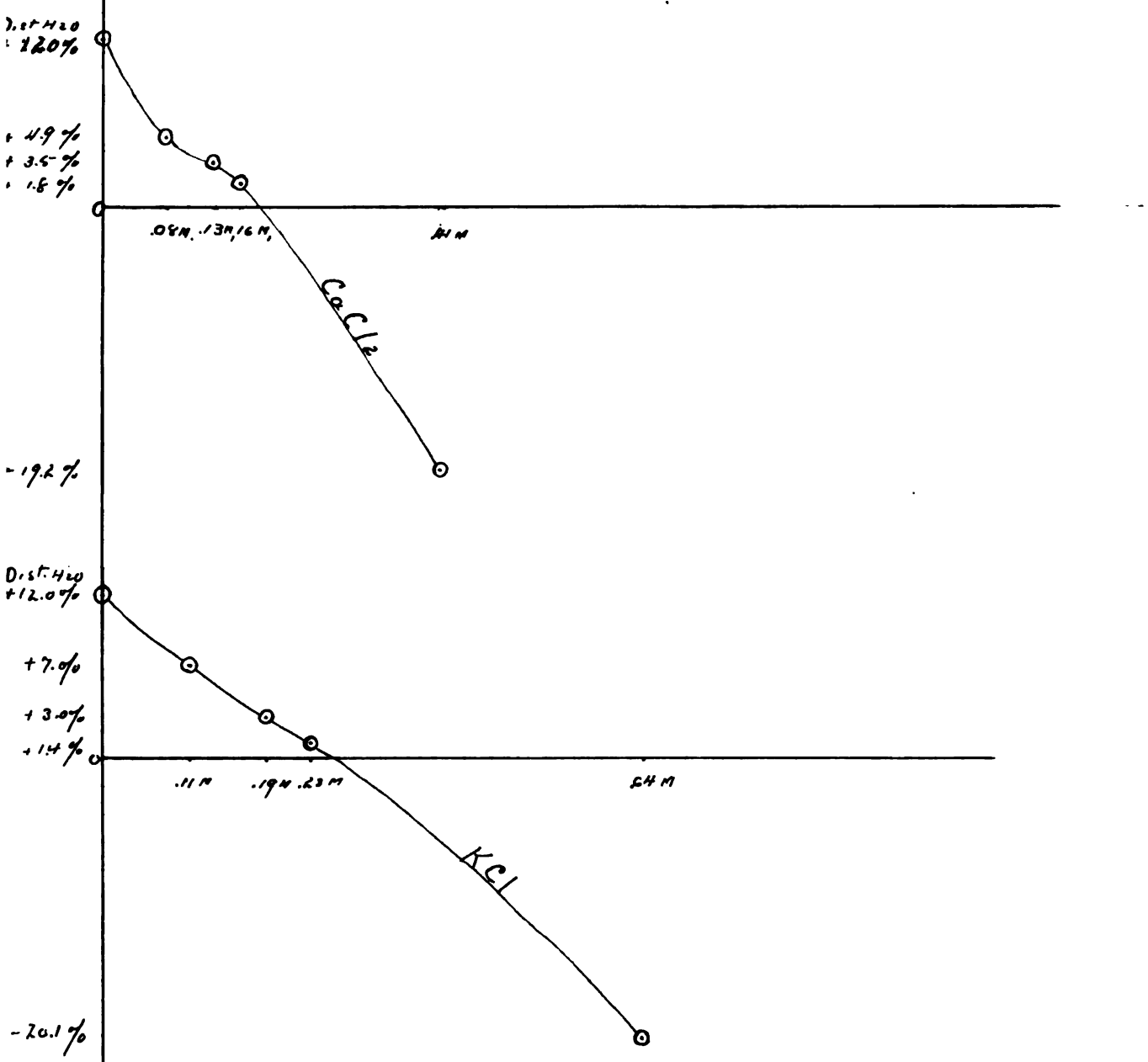
1 " = 2.% gm in ±

Curves based upon eighteen hour observations.



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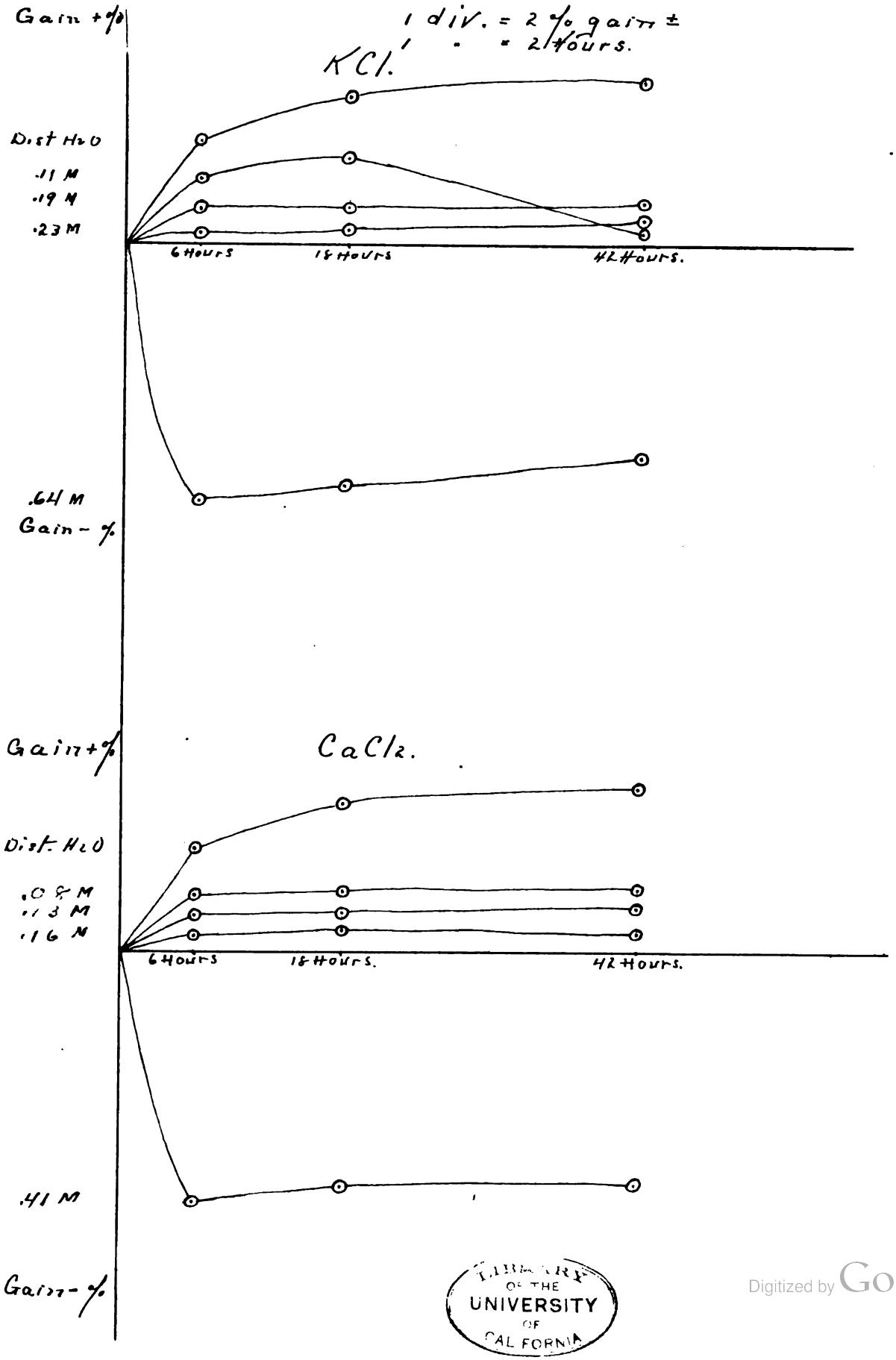

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